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Cost and Performance Report

(MM-0740)

Operational Evaluation of a New Acoustic Technique for UXO Filler Identification

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ACRONYMS AND ABBREVIATIONS

ATC	Aberdeen Test Center
COTS	commercial off-the-shelf
DoD	Department of Defense
EOD	explosives ordnance disposal
ESTCP	Environmental Security Technology Certification Program
HE	high explosive
ID	identification
NASD	Naval Ammunition Support Detachment
NAVEODTECHDIV	Navy Explosive Ordnance Technology Division
NSWC	Naval Surface Warfare Center
PELAN	pulsed elemental analysis with neutrons
POP	plaster of paris
SERDP	Strategic Environmental Research and Development Program
UXO	unexploded ordnance
VNTR	Vieques Naval Training Range

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Development of the acoustic identification technology under this project was performed by the staff at The University of Denver, Denver Research Institute. Key personnel included Dr. Wes Cobb, Senior Research Scientist, and Justin Wiley, Technical Specialist. Key government personnel included Dr. Jeffrey Marqusee, ESTCP executive director, Dr. Anne Andrews, ESTCP deputy director, Dr. Herb Nelson, Munitions Management Program Manager, and their staff. Special thanks go to Mr. Tom Douglas, Lead Program Analyst at NAVEODTECHDIV, for his help with the field testing of the technology. Mr. Larry Overbay and the staff at APG were responsible for the operation of the APG demonstration site.

Technical material contained in this report has been approved for public release.

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1.0 EXECUTIVE SUMMARY

The objective of this work is to demonstrate and validate a new technology to identify the filler material in unexploded ordnance (UXO). This technology, developed under a two-year Strategic Environmental Research and Development Program (SERDP) program, has been tested at several Department of Defense (DoD) lab and range facilities. The ability to correctly identify important inert filler types has been demonstrated on actual ordnance. The purpose of this ESTCP demonstration was to conduct field tests at an active test site to validate filler identification (ID) under field conditions.

The acoustic technique was tested in March 2009 at an active remediation site in Vieques, Puerto Rico. Unfortunately, these tests were disappointing because, even with the three-month "set-aside" effort, the number of ordnance items in the correct size range was very limited. During the test week, the acoustic system was moved from one site to another testing any items that were near the targeted size range. Over a total of about 10 field sites with smaller ordnance, we were able to test about 20 items. Unfortunately, many of these were very corroded and no acoustic signals were received at all through these items.

The multiyear ESTCP field tests showed that, although the technology will not identify all ordnance types and filler materials, it provides a simple, low-cost way to ID some of the most common inert filler materials. The technology works best on fillers that are cast into the shell body and are intimately bonded to the metal walls. Thus, plaster of paris (POP), wax, and cement fillers provide good signals for identification, whereas loose sand and gravel do not. Although signals for other cast filler materials have been measured, high explosive (HE) fillers do not provide strong signals for ID. Although corrosion reduces the amplitude of the received signals, good signals were received in the laboratory for a number of highly corroded items filled with cement and POP. However, as learned during the Vieques tests, the acoustic technique will not work for heavily corroded shells where the case has burst and swollen beyond the nominal outer diameter.

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2.0 INTRODUCTION

The objective of this work is to demonstrate and validate a new technology to identify the filler material in UXO. This technology, developed under a two-year SERDP program, has been tested at several DoD lab and range facilities. The ability to correctly identify important inert filler types has already been demonstrated on actual ordnance. During this demonstration, we conducted key field tests at the active test site to validate filler ID under field conditions for a nonintrusive investigation (e.g., surface UXO only). This report describes the objectives, technology description, demonstration design, and performance assessment parameters for demonstrations conducted at the former Vieques Naval Training Range (VNTR), Vieques, PR.

2.1 BACKGROUND

DoD needs better tools to help its personnel involved in remediation of UXO and nonhazardous items to more quickly and safely identify filler materials. This ability would significantly lower the dangers to personnel and the cost of remediation.

This new filler ID technology utilizes acoustic waves to identify the materials inside sealed UXO. Acoustic waves are high-frequency pressure fluctuations that travel through materials (sound). Small sensors clamped to the outside of the ordnance item send low-energy acoustic waves through the shell walls and filler material. The received signals are processed to determine the characteristic acoustic properties of the filler material. These properties are then compared to a database of properties for known filler materials.

Currently, no cost-effective instrument is in routine use to identify the fillers in UXO. The proposed technology would permit personnel to quickly identify hazardous items and optimize remediation efforts. Significant cost savings can be achieved through more efficient procedures and reduction of false identifications. Currently, 75% of the costs associated with remediation of UXO contaminated sites are derived from excavating and mitigating nonhazardous targets.

The only known technology being developed for filler ID relies on detection of gamma rays emitted by stimulating the ordnance item with a neutron beam. One system that uses this technology is termed pulsed elemental analysis with neutrons (PELAN). PELAN is a man-portable system for explosives detection based on the principle that explosives contain various chemical elements such as H, C, N, O, etc. in quantities and ratios that differentiate them from other innocuous substances. Although PELAN can provide accurate filler ID for larger UXO, it often gives false readings for smaller ordnance because the signal from the explosive is overwhelmed by signals from the surrounding environment.

2.2 REGULATORY DRIVERS

The DoD is faced with significant costs for environmental restoration and compliance with environmental regulations for UXO. To remediate DoD sites, better tools are needed to discriminate between UXO and nonhazardous items. Although great effort has been expended to detect and localize UXO in the ground and underwater, there are currently few devices that can inspect and identify the filler materials. The ability to make a quick and safe identification would significantly lower the risks to personnel and the cost of remediation. In addition to improved speed and safety, the filler ID method must be nonintrusive and operate while the ordnance item is partially or completely uncovered.

3.0 TECHNOLOGY

3.1 TECHNOLOGY DESCRIPTION

The filler ID technology utilizes acoustic waves to identify the materials inside sealed UXO. Acoustic waves are high frequency pressure fluctuations (sound) that travel through materials. Small sensors clamped to the outside of the ordnance item send low-energy acoustic waves through the shell walls and filler material. The spring clamp holds the two acoustic sensors on either side of the casing while the waves are emitted and travel through the case and filler. The portable electronics receive the transmitted wave signal, make the acoustic measurements, and identify the filler material using a preset discrimination model.

As illustrated in Figure 1, the identification method works by matching field measurements of acoustic properties to those in a database of known filler materials. The best reliability is achieved when the filler properties are very specific and do not vary significantly with manufacture or aging. The measurement of velocity and attenuation must also be accurate so that the acoustic properties of the material can be discriminated. The known properties of the case are also used in these calculations to remove the influence of the case. That way, the acoustic properties of the filler can be measured independently of the container.

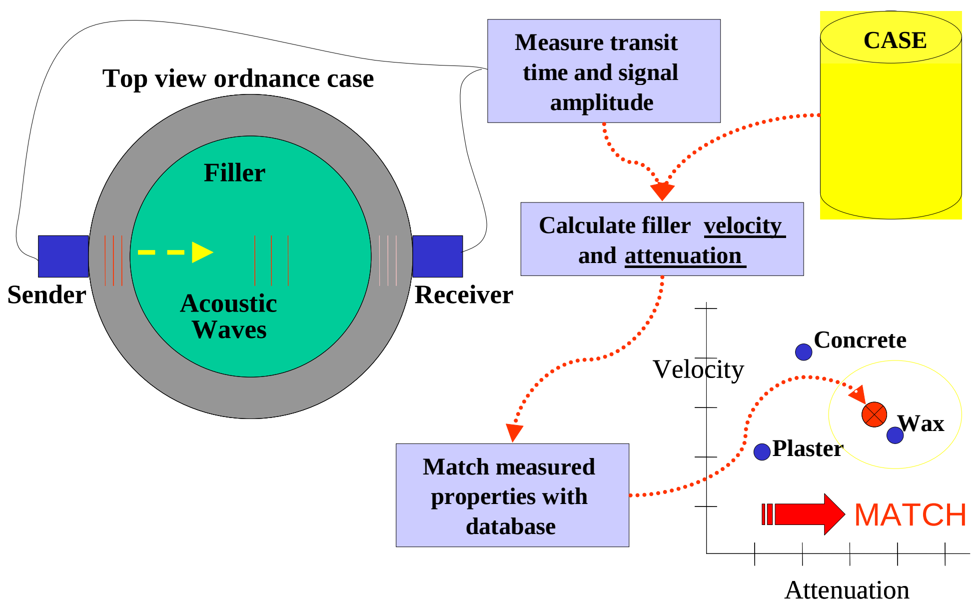

Figure 1. Sketch of the filler identification system shown attached to an artillery shell.

The filler ID technology is based on noninvasive acoustic technology developed to characterize fluids traveling through pipes used in manufacturing processes. Through an earlier SERDP project (UXO-1382, 2003-2005), this technology was adapted for use on solid-filled ordnance shells, and the capability for material identification was demonstrated. The acoustic filler ID technology has been proven during a two-year SERDP program of device development and lab/test-site evaluation. This project was a response to a Statement of Need for filler ID technology identified by SERDP for FY 2003. After the first prototype ID devices were developed, they were tested at three DoD test sites, including the Naval Surface Warfare Center (NSWC) Crane, Army Aberdeen Test Center (ATC), and the Navy Explosive Ordnance Technology Division (NAVEODTECHDIV). Ordnance items used in these tests included a wide variety of mortars and shells ranging in size from 60 mm to 5-inch 38-caliber. Fillers included both inert and HE materials. The ability to identify buried, partially uncovered items was tested at NAVEODTECHDIV in November 2008.

During the current ESTCP project, the sensor has been redesigned and the technology field-hardened for use on UXO for the demonstrations described here.

3.2 ADVANTAGES AND LIMITATIONS OF THE TECHNOLOGY

The earlier SERDP tests showed that the technology provides a simple, low-cost way to identify some of the most common small-ordnance filler materials. The technology works best on fillers that are cast into the shell body and are intimately bonded to the metal walls. In this case, the sound waves easily travel from one side of the shell through the walls and center of the filler and can be received on the opposite side. Thus, POP and cement fillers provide good signals for identification, whereas loose sand and gravel do not. A filler ID is only provided when signals with these characteristics are received. A "good" signal has characteristic features that distinguish it from noise signals. For inert materials, the signal received through the filler has characteristics that clearly differentiate it from the "case noise" that will always be present. Case noise is caused by acoustic waves that travel through the case walls only and do not enter the filler. These waves are considered noise because they do not provide any information useful to filler ID.

Although this technology is new, the earlier SERDP study provided a great deal of information on the ultimate capabilities and reliability of the technology. First, the current acoustic technique shows good identification accuracy for inert fillers based on data clusters for velocity and attenuation. Second, acoustic technology operates best for smaller shells that do not significantly attenuate the signal traveling through the filler (40 mm to 81 mm). Third, if a good quality signal is received through the item, the identification is highly accurate. In all cases, a good quality signal is easily distinguished from a poor quality signal. Filler ID should not be attempted on the basis of a poor quality signal. Fourth, several new techniques to improve signal quality have been developed and tested. Each of these techniques shows promise for improving the signal quality for curved shells, corroded items, and highly attenuating fillers. Finally, throughout this study, no safety issues have developed, even with fused items.

The only known alternative technology is PELAN, discussed in Section 2.1, and which has the disadvantage of being accurate only for large UXO. This acoustic technology fills the need to identify filler material in small ordnance.

4.0 PERFORMANCE OBJECTIVES

Table 1 lists the performance objectives for the acoustic testing at VNTR. These objectives are considered critical to the eventual utility of the technique. As stated earlier, the VNTR tests were considered important because they could provide the first indications of performance for many actual fired-and-recovered UXO items.

Table 1. Performance objectives.

Performance Objective	Metric	Data Required	Success Criteria
Quantitative Performance Objectives			
Detection of good signals for filler ID	Percentage of inert items with good signals received	• Acoustic signals received for multiple sensor placements on items	> 80%
Correct ID of inert-filled items	Accuracy of filler ID for items with good signals	• Acoustic signals received for multiple sensor placements on items	> 95%
Qualitative Performance Objectives			
Ease of mounting sensors to various items	Ease of clamping sensors on item at pre-selected location	• Evaluation sheet completed by technician	Sensor clamp does not have to be repositioned on item

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5.0 SITE DESCRIPTION

5.1 SITE SELECTION

VNTR was selected because it is an active UXO remediation site where demonstration of a new technology could be arranged. In addition, because of the wide variety of ordnance fired here over the many years of operation, we expected to find items in the required size range for the acoustic tests (< 90 mm). Other DoD active sites were considered but did not appear to have the required size, range, or type of ordnance items.

5.2 SITE HISTORY (TAKEN FROM REFERENCE)

Vieques Island has a land area of approximately 33,000 acres, and is located in the Caribbean Sea approximately 7 miles southeast of the eastern coast of the main island of Puerto Rico (Figure 2). The former Naval facilities are located on the eastern one-third (i.e., former VNTR) and western one-third (i.e., former Naval Ammunition Support Detachment [NASD]) of the island, with the communities of Isabel Segunda and Esperanza located in the center of the island.

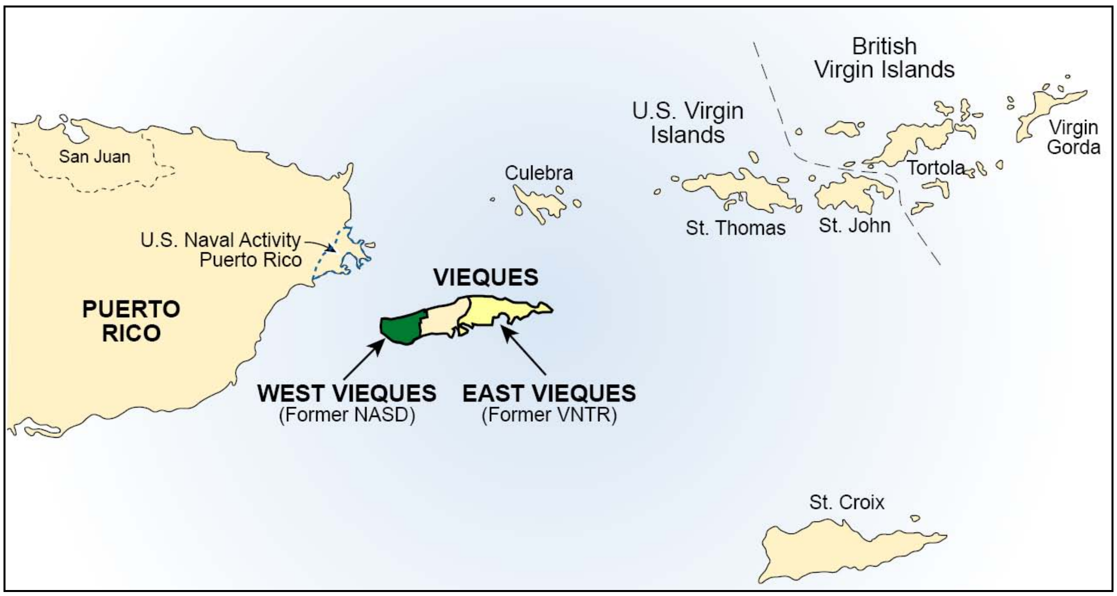
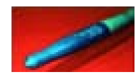


Figure 2. Location of the VNTR site.

As part of normal UXO operations, test ordnance items were removed from the surface, and if judged “safe to move,” transported to the “demolition sites.” We asked VNTR operations to begin collecting smaller ordnance items that are judged to be inert filled starting January 2009. To avoid possible damage and interference with the acoustic tests, these items were not be “demoed” until after the acoustic tests. Table 2 shows examples of the type of ordnance set aside at VNTR.

Table 2. Examples of ordnance types set aside for the acoustic tests.

QUANTITY TO TEST	ITEM	# TESTED AT 5 ORIENT.	CLAMP LOCATION	PHOTO/DRAWING
4	60 mm M50A2 TP/M49A2 HE Mortar	2	3.5 cm below fuze on gas check band	
4	81 mm M375 WP mortar wo/fin shroud – 90 mm fuze	2	7.6 cm below fuze	
6	2.75-inch (70 mm) M230 rocket warhead	2	20 cm below fuze	
6	76 mm Mk 201 projectile w/fuze—no inert lettering	2	4.3 cm below fuze	
20	TOTALS	8		

6.0 TEST DESIGN

This section describes the field procedures, equipment settings, and data requirement forms that were used for the demonstration tests at Former Naval Facilities Vieques. The objective of these tests was to demonstrate the acoustic technology on recovered UXO. Unlike testing at the prior controlled sites, the active site provided a source of actual UXO shells with original fill materials and with various degrees of corrosion and dents. In addition, by testing many items, practical limitations for the technology were identified.

The types of ordnance items desired for the active-site testing are listed below:

- Shells that have a known inert fill or the fill can be identified later by destructive testing
- Recovered (and set-aside/stored) items
- Shell diameters from 40 mm to 81 mm
- Shells that are completely sealed and have solid fill materials (e.g. plaster, wax and cement), not sand, loose gravel, or burster tubes
- Items that have various degrees of corrosion but are not significantly dented in the area near the maximum diameter.

The primary restriction on the ordnance test items was that the size must be 81 mm or less. This is due to the high acoustic attenuation in most inert-fill materials and the losses in the acoustic signal strength as it travels through large shells. Although large shells may be workable in the future with improved sensors, the technology to be tested was limited to 81 mm and below.

6.1 CONCEPTUAL EXPERIMENTAL DESIGN

The acoustic testing took place at several demo sites located within the live impact area of VNTR. Actual item testing took most of the time and involved locating and marking the ordnance item for the collection area, clamping the acoustic sensors, and recording the data. All items were tested using the procedures detailed below. The various items were tested at or near the locations where they were collected. All power for the acoustic instruments was provided by an AC inverter attached to a truck battery. At the conclusion of testing at each site, the items were replaced back in the collection pile for later demolition. Note that each item had a number painted onto its body for later identification after the demo.

6.2 SITE PREPARATION

Since all testing will take place at the demo sites, little site preparation was required. Listed below are the setup preparations that needed to be made before the testing:

- Collect ordnance items to be tested at the demo sites.
- Locate a portable tent in case of poor weather during testing.
- Setup and test the shear cutting tool available at the Central Processing Center.

6.3 SYSTEM SPECIFICATION

A key objective of the current ESTCP project was the development of a clamp-on sensor and a portable electronic system to make the acoustic measurements. The clamp is an important part of the filler ID system and has been designed so that it can be attached from only one side of the shell. It must hold the acoustic sensors rigidly to the sides of deformed, corroded ordnance bodies while maintaining good alignment. Figure 3 shows the clamp attached to an 81 mm projectile body. Note that this clamp can be attached while working from one side of the shell. The soil does not have to be removed all the way around the shell case. In addition, the shell needs to be exposed only in a central area near the maximum outer diameter, often near the obturating ring.

Figure 3. Photo of the sensor clamp attached to an 81 mm inert-filled mortar.

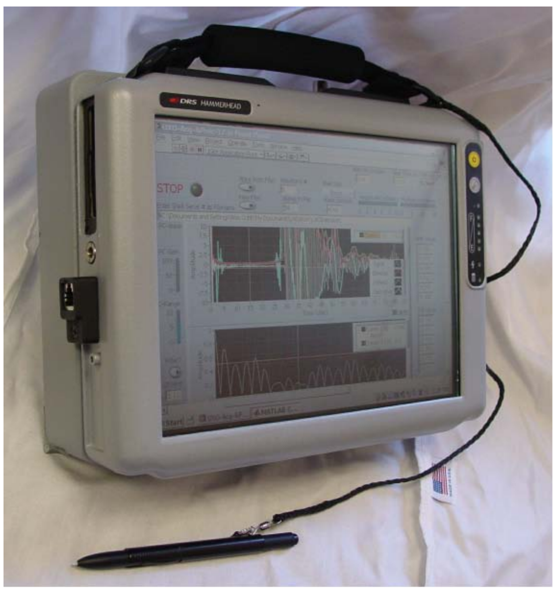


Figure 4. Data recording system with piggyback acoustic electronics.

The portable electronics system was developed to record and store acoustic signals taken using the clamp-on sensors. Figure 4 shows a photograph of the portable system, which consists of a hardened touch-panel computer and piggyback acoustic electronics. The cables from the sensor clamp attach directly to the electronics case mounted on the back of the computer. The data acquisition system processes the received acoustic signals and measures the acoustic velocity through the filled test body.

6.4 DATA COLLECTION PROCEDURES

The procedure for recovered/set aside items is as follows:

1. If necessary, move the item from the collection area to a nearby location on the ground.
2. Clean the item around the specified clamp location with water and apply acoustic gel.
3. Select the proper clamp for the ordnance item size.
4. Clamp sensors to the specified location on the item (circumferential position A).

5. Photograph the clamp and ordnance item showing general orientation of the clamp.
6. Move to system location; connect sensor cables.
7. Enter test ID and start signal recording.
8. Observe signal quality and determine if a “good” signal is present (see above).
9. Wait for a standard series of six readings to be recorded and stop recording.
10. Repeat steps 7-12 at two other clamping locations around the circumference of the item (circumferential position B and C).
11. Stop testing and wipe/clean the sensor faces.
12. Move the item to the “demo” pile and begin again with the next item.
13. Upload recorded data to a “flash drive” for safekeeping.

6.5 VALIDATION

For these demonstration tests, the only validation was to determine the actual filler type in the inert items used for the tests. This was done soon after the tests using a mechanical shearing device located at the Central Processing Center. Each item was marked with a painted number so that the filler type (wax, plaster, etc.) could be visually identified and recorded against this number on the test matrix after shearing (see Table 4).

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7.0 DATA ANALYSIS PLAN

Appendix B shows an example of the data table that was produced for each test item. The acoustic velocity and attenuation values to be used in the discrimination model for filler ID came from this data record. The velocity of the filler material was computed using the methods described in the ESTCP Final Report.

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8.0 PERFORMANCE ASSESSMENT

This section summarizes performance testing at the controlled site (NAVEODTECHDIV) and the active site (Vieques, PR). Subsections below address specific objectives detailed in Section 4.

8.1 EASE OF MOUNTING SENSORS TO VARIOUS ITEMS

Controlled site tests of the acoustic technique were made during November 18-21, 2008, at NAVEODTECHDIV (Indian Head, MD). The objective was to confirm proper operation of the field devices on inert items in a more representative field situation than is available at a laboratory. Filled ordnance items were partially buried and then uncovered to simulate operations by remediation personnel at a response site (see Figure 5). The inert fills included plaster, wax, cement and liquid. In addition, several shells were empty or had loose fills (i.e. not case bonded). The items were placed in various orientations in the ground to test for difficulties in clamping the acoustic sensors.

Figure 5. Explosives ordnance disposal (EOD) personnel clamping the acoustic sensors to a corroded 2.75-inch warhead.

Throughout the testing, similar signals were measured for the shell in-ground and aboveground (table top). For 95% of the shells, good in-ground readings were obtained. In addition, we measured only a small 3% difference in acoustic velocity between the in-ground and table measurements. Thus these tests showed that clamping the acoustic sensors to a shell should be possible for most active site conditions. In addition, we found that the average time to clamp to a shell and receive a good signal was 1.2 minutes. This time seems practical for UXO cleanup application.

8.2 DETECTION OF GOOD SIGNALS FOR FILLER ID

Testing of the acoustic technique at an active test site in Vieques, PR was completed during the week of March 30, 2009. The objective of this test was to confirm that good acoustic signals could be obtained for realistic field conditions on actual fired and recovered ordnance. Because small (<90 mm) UXO items are needed for the acoustic tests, and we learned that only a few small items were currently being recovered at Vieques, we had made arrangements with the UXO supervisor to collect smaller items after they are uncovered and moved to the demo sites.

Acoustic testing took place at these sites before the items were damaged by the demolition charges. In addition to the small, set-aside items, we tested large, cement-filled, MK82 bombs. Recent studies suggested that, due to the very low attenuation in cement, the acoustic waves should be able to penetrate the 18-inch diameter cement and allow filler ID.

Figure 6. Filler ID testing at an active response site (Vieques, PR).

Unfortunately, these tests were disappointing because, even with the three month set-aside effort, the number of items in the correct size range was very limited. This was the case despite the fact that small items were routinely uncovered when this test site was selected in 2006.

During the test week, we moved the acoustic system from one demo site to another, testing any items that were near the targeted size range. Over a total of about 10 field sites with smaller ordnance, we were able to test about 20 items. Unfortunately, many of these were very corroded and no acoustic signals were received at all through these items. After acoustic testing, the items were demolished using explosive charges and the filler identified thought visual inspection.

Table 3 shows the acoustic test results for the 23 items. Note that only 11 of these items were in the target size range for the improved acoustic sensor clamps (60-81 mm). The larger items were tested using the older, unimproved sensor clamps developed during the SERDP study. Of these 11 correctly sized items, only one shell turned out to be filled with an inert, plaster material suitable for acoustic testing. This plaster filled shell (#8) did provide a good acoustic signal with an arrival time indicative of a plaster fill.

Table 3. Acoustic test results.

ITEM #	ITEM NOMENCLATURE	GRID LOCATION	FILLER (VERIFIED)	COMMENTS
1	5 inch (HE?)	K2D0F6	HE	No readable signal
2	5 inch	K2D0F6	HE	No readable signal
3	5 inch rocket	K2D0F6	wax	No readable signal
4	5 inch (HE?)	K2D0F6	HE	
5	4.5 inch (HE?)	K2D0F6	HE	No readable signal
6	75 mm (HE?)	K2D0F6	HE	No readable signal
7	75 mm empty	K2D0F6	empty (hollow)	No readable signal
8	2.75 inch	C7	plaster	Good acoustic signal and ID
9	BDU 45	Consolidation pile near CPC	cement	Good acoustic signal and ID
10	81 mm	MRS 9 - PIKA		No readable signal
11	75 mm	J2E7G7	HE	No readable signal
12	76 mm	J2E7G7	HE	No readable signal
13	2.75 inch	J2F0A2	HE	No readable signal
14	90 mm flare canister	J2F0A2	ILLUM	No readable signal
15	2.75 inch	J3F2C8	empty (hollow)	No readable signal
16	2.75 inch	J3F2C8	empty (hollow)	No readable signal
17	2.75 inch	J3F2C8	empty (hollow)	No readable signal
18	2.75 inch	J3l3B3		No readable signal
19	105 mm	J3E3A4		No readable signal
20	105 mm	J3E3A4		No readable signal
21	BDU 45	Consolidation pile near CPC	cement	Good acoustic signal and ID
22	BDU 45	Consolidation pile near CPC	cement	Good acoustic signal and ID
23	BDU 45	Consolidation pile near CPC	cement	Good acoustic signal and ID

All of the other items that were empty or filled with HE gave acoustic signals indicative of “case noise” only, as expected (see Section 3.2). Recall that the acoustic technique does not read HE because of the very high attenuation in these materials, and that only inert fills (wax, plaster and cement) can be identified.

8.3 CORRECT ID OF INERT FILLED ITEMS

Besides the one plaster-filled shell, the only other items with good acoustic signals were the four cement-filled 18-inch diameter MK82 bombs. For these very large items, magnetic sensor clamps were attached to opposite sides near the middle of the case. For each of these items, the acoustic signal for the bomb arrived at the correct time for the path length through the case and cement filler (Table 3).

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9.0 COST ASSESSMENT

Table 4 shows the cost model for the acoustic filler ID technology. During the demonstration, manpower cost estimates were made using stopwatch measurements, as described above. Instrumentation costs were estimated based on existing payments for the purchased commercial off-the-shelf (COTS) components as well as fabricated components.

Table 4. Cost model for the acoustic filler ID technology.

Cost Element	Data that was tracked	Results
Instrument cost	Component costs and integration costs • Engineering estimates based on current development • Consumables	COTS portable PC: $5000 Fabricated acoustics electronics: $2000 Integration: $2000 Software: $1000 $10,000
Mobilization and demobilization	N/A	
Site preparation	No unique requirements since equipment is portable and manual	
Instrument setup costs	Unit: $ cost to set up and calibrate Data requirements: • Hours required • Personnel required • Frequency required	Site setup: $50 ½ hour unpack and test: ($100/hr)
Survey costs	Unit: $ cost per ordnance item Data requirements: • Hours per item • Personnel required	Operator time (~6 min@100/hr) $10 Consumables: $2
Detection data processing costs	N/A	
Discrimination data processing	Unit: $ per ordnance item • Time required • Personnel required	Later review by expert may be required but cost not known at this time

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10.0 IMPLEMENTATION ISSUES

Unfortunately, because of the limitations of the active test site, this study did not provide an adequate validation of the acoustic filler ID technology. The Vieques, PR, site just did not provide inert-filled UXO of the required size for testing the acoustic technique. In addition, all efforts to identify an alternate field site with appropriate UXO have failed.

Although some of the test results were encouraging (MK82 cement bombs), much more field data is required to adequately evaluate the acoustic technique. Suitable testing of the current acoustic technology would require a large number of small (<90 mm) inert filled items that had low corrosion (case is not swollen and burst open).

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APPENDIX A

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APPENDIX B

SAMPLE DATA TABLE

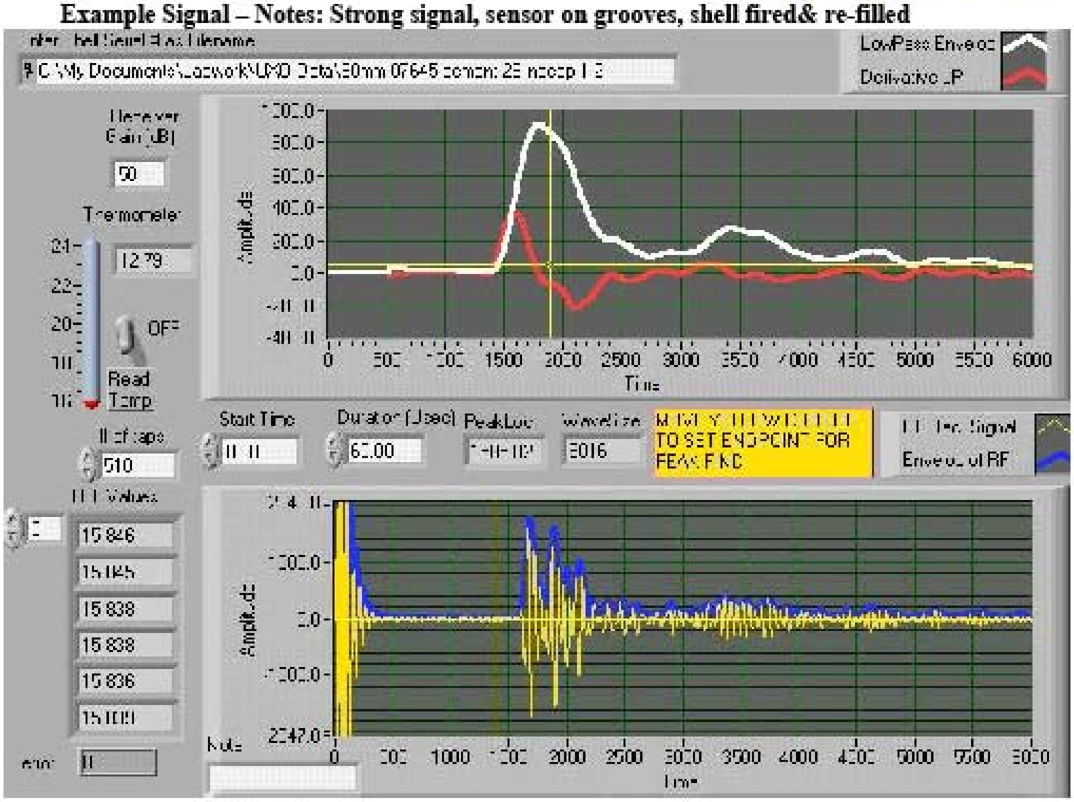
Ordnance Data for Item # 21

Size	Body	Filler	Condition	WallThk.	DODIC	NSN
60mm	Mk47	Cement-Not Orig. Fill	Corroded	0.59		EOD-07645

Measurements

MV	MA	VV	VA	SF	OF	CO	SG	DA	LO	TE
.345	-	.361	1.87	25	3.5		50	8/09/05	DRI	20
.351		.361	1.87	-	-		-	-	-	-
.346		.361	1.87							

Example Signal – Notes: Strong signal, sensor on grooves, shell fired& re-filled



MEASUREMENTS CODES:

MV – Measured Velocity (cm/usec)
MA – Measured Attenuation (dB/cm)
VV – Validated Velocity (Lab - cm/usec)
VA – Validated Attenuation (Lab - dB/cm)
SF - Sensor Frequency (MHz)
OF – Location Offset (sensor from top – cm)
CO – Configuration (sensor caps, etc.)
SG – Sensor Gain (dB rel.)
WallThk. – Case Wall Thickness (cm)
DA – Date
TE – Temperature (°C)
LO – Test Location

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